Applying Screenings in Lean Concrete Base & Cement Treated Base Pavement

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Abstract

The supply of natural sand that is used in lean concrete as a fine aggregate is becoming more difficult to secure due to exhaustion of the source. Therefore, this study was conducted to resolve the exhaustion of materials and economize in construction expenditure by applying screenings, which is a byproduct of crushed rock from quarry, as an alternative to natural sand. As a result of comparative analysis on application of screenings and natural sand which was conducted in the first step, it could be inferred that the use of screenings as a fine aggregate showed better strength in both granite and limestone aggregate sources.

Verification of actual application of screenings was conducted in the second step, after test construction and tracing survey. The compressive strength of screenings applied in this case was greater than that of natural sand by 113%, the compaction density of screenings applied in this case was greater than that of natural sand by 102%, and the workability of screenings was sufficient for field construction.

Thus, it is expected that application of screenings to construction in the field will contribute to the cost saving, material recycling and the protection of environment.

1. Introduction

Screenings refer to a byproduct resulting from the process of making aggregates for asphalt mixture or cement concrete. These pulverized fine aggregates are very useful since they can be obtained from manufacturing of raw materials and without complicated pre or post-treatment unlike other construction wastes.

Nevertheless, the use of screenings as an aggregate is still minimal. After “Guideline in Applying Screenings for Sub-base Course and Anti-Frost Layer (Korea Expressway Corporation, 2000)” was established, screenings have been used as a substitute for fine aggregates of sub-base course and anti-frost layer within 30 percent weight range of mixed aggregates.

In this study, the ways to utilize screenings, previously only limited to sub-base course and anti-frost layer, as a pavement material for lean concrete and cement treated bases were studied.

2. Preparation Experiment for Application of Screenings

Lean concrete preparation experiment using screenings is a step for deciding whether screenings can substitute for the sand which is used as a fine aggregate for lean concrete, and if it is substitutable, the ratio which screenings can substitute the sand for. To test the applicability of screenings, the ratio of screenings to sand replacement was changed in ten percent increments.

■ Compressive Strength Test

The aggregates used in this test were two types of aggregates, the granite and limestone. For coarse aggregates, 40mm and 19mm were used, and for fine aggregates, natural sand and screenings were used.

Design strength of lean concrete specifies compressive strength as greater than 5MPa on the 7 day and a value 1~1.2 times (extra coefficient) greater than the compressive strength as the target strength in mix design. In this study, 5.8MPa was used as the target strength, which is 1.15 times greater than the compressive strength.

Compressive strength test results of granite and limestone as test specimens are as Table 1 and Figure 1. The resulting values of granite and limestone test specimens were greater than the target strength 5.8MPa. Compared to the test specimen of lean concrete which used 100% sand, granite and limestone showed approximately 3.6~5.8MPa and 1.3~6.0MPa greater strength, respectively.

Table 1. Compressive Strength Test on Lean Concrete using Screenings

Screenings (%)	Granite (MPa)	Limestone (MPa)
0	6.5	9.0
10	10.6	10.3
20	11.7	12.2
30	10.2	14.9
40	11.6	13.5
50	11.6	13.1
60	12.3	13.8
70	11.3	14.4
80	12.0	14.3
90	10.1	12.6
100	11.1	13.6

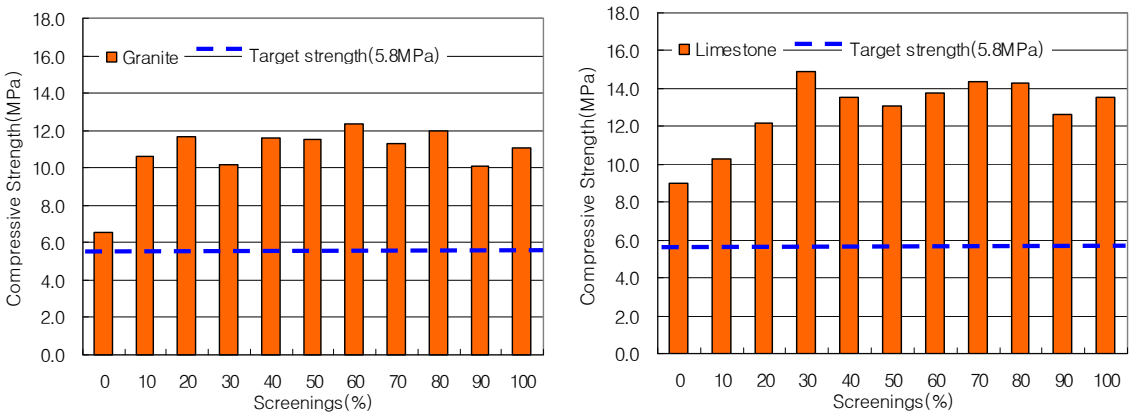


Fig. 1 Compressive Strength Test on Lean Concrete using Screenings

3. Test Construction

■ Outline of Test Construction

As a result of preparation experiment, lean concrete test specimens that used screenings displayed a value greater than the compressive strength standard 5.8MPa for the 7 day and also greater than the lean concrete that used sand. In terms of strength, it could be inferred that screenings can substitute 100% of natural sand used for lean concrete. To apply this in a field setting, a test construction was implemented.

Test construction was done for the highway interval between Pyeongtaek and Anseong, and extended construction and the outline are as Figure 2. Figure 3 is photographs taken from test construction.

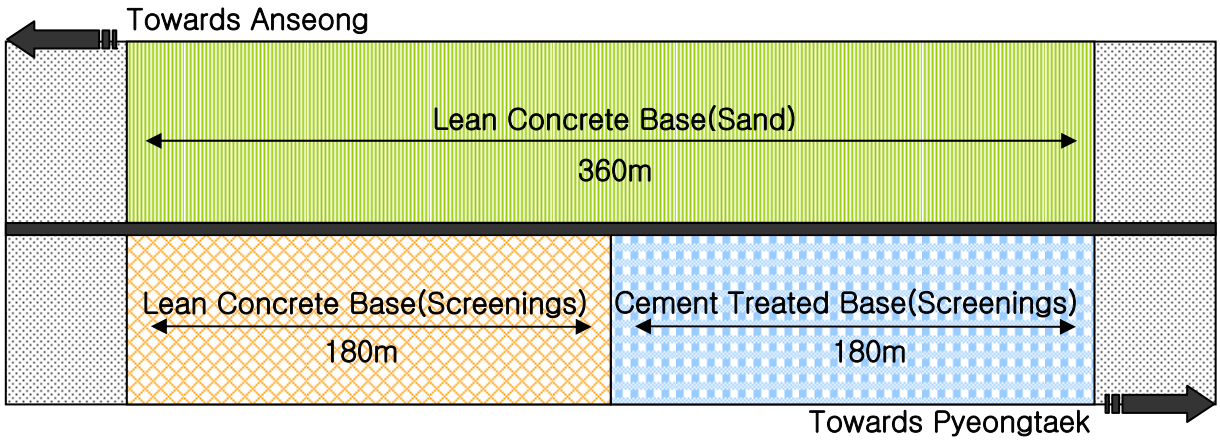


Fig. 2 Outline of Test Construction Intervals

(a) Paving lean concrete (b) Compacting lean concrete

Fig. 3 Test Construction Images

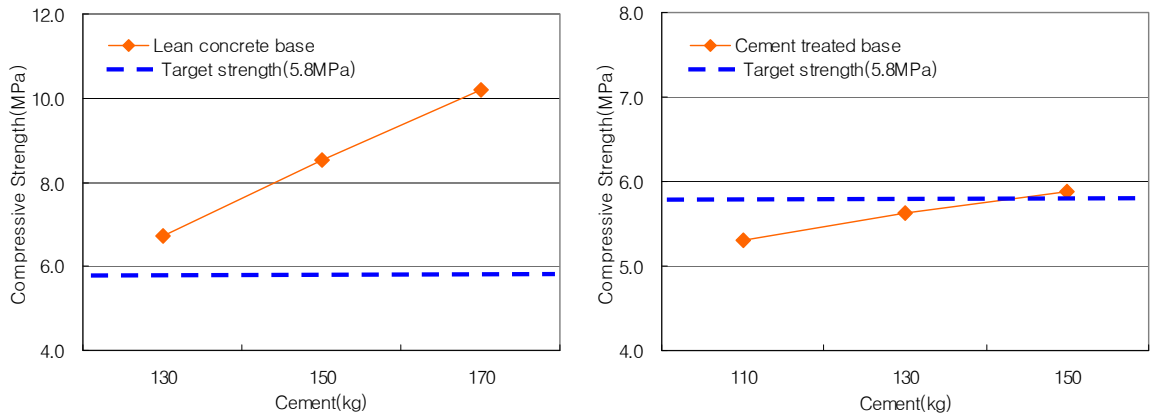
■ **Mix Design**

Aggregates used for mix design in test construction were 32mm and 19mm coarse aggregates and screenings collected from a quarry, the source of granites, as fine aggregates. Table 2 shows the result of compressive strength test on lean concrete and cement treated bases performed on the 7 day.

For the compressive strength test, three test specimens were created for each unit weight of cement to measure the compressive strength of test specimens for different unit weights of cement. For lean concrete, all unit weights of cement satisfied the target strength, and minimum cement weight 150kg specified in the highway specification was used as the unit weight of cement. Since cement treated base does not have a specified minimum cement weight, 130kg unit weight of cement which satisfies the target strength 5.8MPa was used as shown in Figure 4(b). Specified mix ratio is as Table 3.

Table 2 Compressive Strength of Lean Concrete and Cement Treated Base on the 7 Day

Unit weight of Cement (kg)	Compressive Strength (MPa)	
	Lean concrete base (screenings)	Cement treated base (screenings)
110	-	5.3
130	6.7	5.6
150	8.5	5.9
170	10.2	-



(a) Lean Concrete (b) Cement Treated Base

Fig. 4 Result of Compressive Strength Test for Different Unit Weights of Cement

Table 3 Table of Lean Concrete Mix (surface dry)

Classification	Cement (kg)	Water (kg)	Aggregate		
			32mm	19mm	Screenings
Lean concrete base (screenings)	150	106.7	852.9	426.6	864.5
Cement treated base (screenings)	130	109.3	860.9	645.9	654.5

4. Tracing Survey of Test Construction Interval

In this study, plate load, falling weight deflectometer, compressive strength, and core specimen density tests were performed to assess the commonality of pavement interval (lean concrete and cement treated bases) where screenings was applied for.

■ **Plate Load Test**

A plate load test was performed in accordance with KS F 2310 to measure the modulus of subgrade reaction(K_{30}) of the test construction site. Figure 5 shows the photographs taken during the plate load test.

Fig. 5 Plate Load Test

The result of plate load test showed highest modulus of subgrade reaction of 40MPa for lean concrete base that used screenings as shown in Table 4. Regular lean concrete base with sand showed 32MPa, and cement treated base was measured as 17MPa. Figure 6 shows pressure-deflection curve for different intervals.

Table 4 Results of Plate Load Test

Classification	Pressure (MPa)	Deflection (cm)	K_{30}
Lean concrete base (screenings)	1.25	0.031	40
Lean concrete base (sand)	1.25	0.039	32
Cement treated base (screenings)	1.25	0.074	17

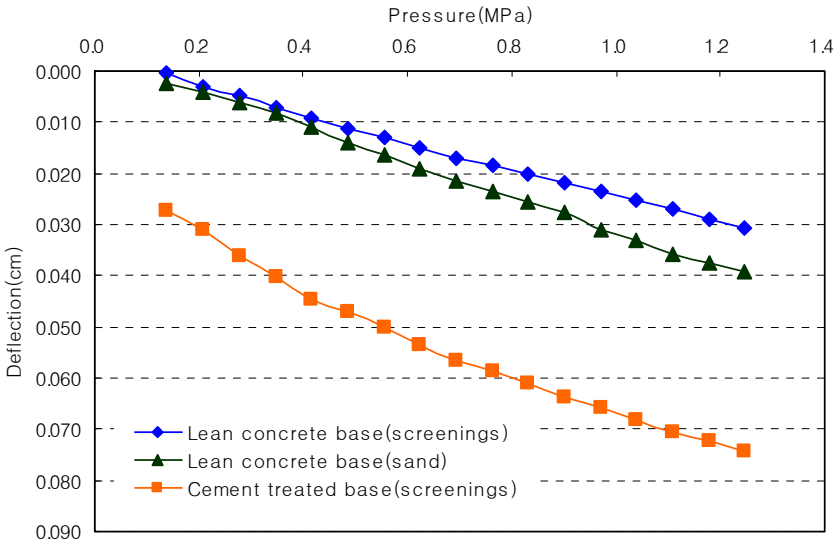


Fig. 6 Comparison of Pressure-Deflection for Different Intervals

■ Falling Weight Deflectometer

Falling weight deflectometer (FWD hereinafter) simulates actual traffic load to relatively accurately measure the physical property of each layer of pavement and is frequently used for evaluating structural capacity of pavement. In this study, the equipment used for analyzing lean concrete base and cement treated base is as shown in Figure 7.

Fig. 7 Falling Weight Deflectometer

Results of FWD for three test construction intervals of lean concrete base (screenings), lean concrete base (sand), and cement treated base are as Figure 8, and deflection was greatest for the cement treated base. Both of lean concrete bases with screenings and sand showed a similar level of deflection.

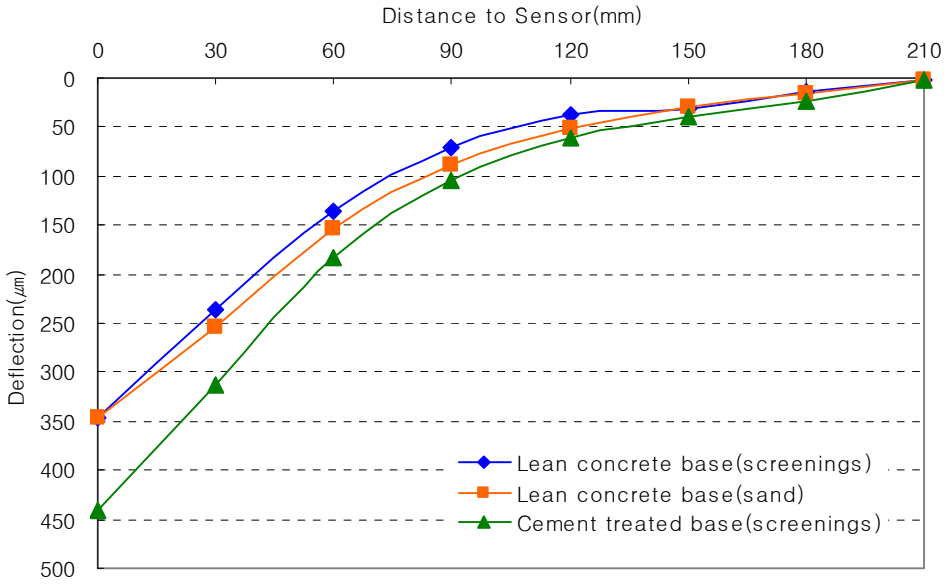


Fig. 8 Result of FWD for Each Interval

■ Compressive Strength Test

To measure the compressive strength of lean concrete and cement treated bases, cores were collected and water-immersed. After water immersion, the compressive strength was measured as shown in Figure 9.

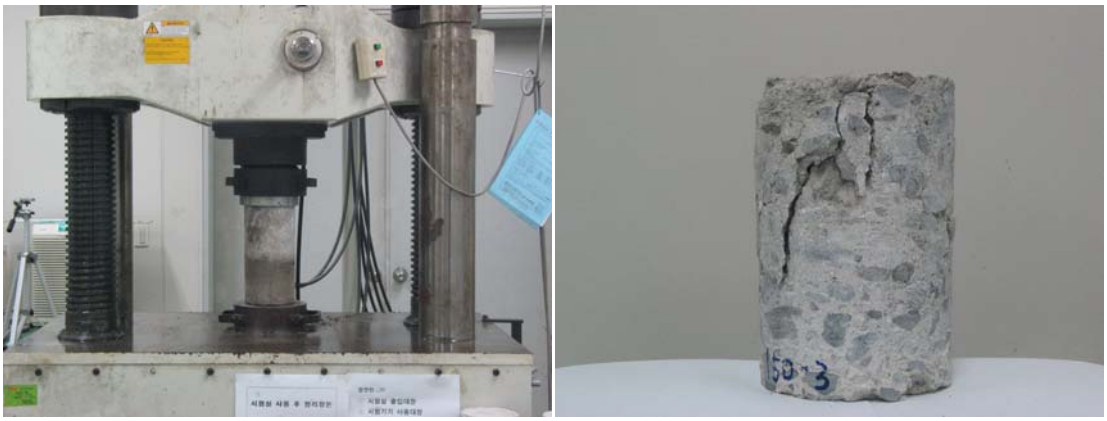


Figure 9 Images of Compressive Strength Test

Among results of compressive strength test, lean concrete base with screenings showed the highest compressive strength of 8.7MPa as described in Table 5. Regular lean concrete and cement treated bases showed 7.8MPa and 4.9MPa, respectively. Lean concrete base with screenings had approximately 1.13 times higher compressive strength than the lean concrete base with sand.

Table 5 Test Construction Core Specimen Compressive Strength Test

Classification	Lean concrete base (screenings)			Lean concrete base (sand)			Cement treated base (screenings)		
	1	2	3	1	2	3	1	2	3
Compressive Strength (MPa)	9.3	8.2	8.7	8.1	7.1	8.0	4.7	4.7	5.2
Mean	8.7			7.8			4.9		

■ **Core Specimen Density Test**

Results of core specimen density test at the site showed 2.260g/cm^3, 2.214g/cm^3, and 2.229g/cm^3 for lean concrete (screenings), lean concrete (sand), and cement treated bases, respectively. Comparison between lean concrete bases that used screenings and sand showed that the lean concrete base with screenings had density approximately 1.02 times greater than the lean concrete base with sand. Table 6 lists the results of core specimen density test.

Table 6 Core Specimen Density Test

Classification	Lean concrete base (screenings)			Lean concrete base (sand)			Cement treated base (screenings)		
	1	2	3	1	2	3	1	2	3
Density (g/cm^3)	2.279	2.235	2.265	2.227	2.211	2.204	2.232	2.228	2.226
Mean	2.260			2.214			2.229		

5. Conclusions

In the study, indoor test and field test construction were performed to apply screenings as a substitute of natural sand for lean concrete and cement treated bases. Indoor test verified if screenings can substitute natural sand, and if possible, to which degree. The result showed 100% of substitution rate. This result was used in test construction to check the field applicability and commonality.

Key conclusions from the study are as follows.

⑴ 150kg of unit weight of cement was used for the target strength of lean concrete base with screenings, and 130kg of unit weight of cement was used for the target strength of cement treated base.

⑵ Compressive strength of all lean concrete specimens mixed using granite and limestone screenings was higher than the target strength 5.8MPa and was higher for the lean concrete specimen with sand as well.

⑶ In preparation experiment, the result of compressive strength test on specimens created with screenings showed 6.5~12.3MPa for the specimens made with granites, which is approximately 1.7~2.1 times greater than the design strength. For limestone specimens, the result of compressive test was 9~14.9MPa, which is approximately 1.8~2.6 times greater than the design strength.

⑹ In plate load test performed during tracing survey using test construction, lean concrete base that used screenings showed 422kg/cm^3, regular lean concrete base showed 325kg/cm^3, and cement treated base showed 173kg/cm^3 of modulus of subgrade reaction.

⑺ In FWD test, relative deflection was highest at 441 ㎛ for the cement treated base interval. The deflection was 347 ㎛ for sand-applied lean concrete base interval and 346 ㎛ for screenings-applied lean concrete base interval, which had the lowest deflection.

⑻ Results of compressive strength test on field core specimen in the test construction intervals showed 8.7MPa and 7.8MPa for lean concrete base intervals with screenings and sand, respectively. The interval with screenings showed 1.13 times greater strength.

⑼ Based on results from the study, standard mixing ratios of lean concrete base with screenings and cement treated base are organized as shown in Table 7.

Table 7 Standard Mixture Ratio of Lean Concrete and Cement Treated Bases

Classification	Cement (kg)	Water (kg)	Aggregate(kg)		
			32mm	19mm	Screenings
Lean concrete base(screenings)	150	106.7	852.9	426.6	864.5
Cement treated base(screenings)	130	109.3	860.9	645.9	654.5

Based on results derived from this study, it can be inferred that industrial byproduct screenings can be applied in a real setting and can substitute natural sand, which is always not enough in road construction. The substitution effect is expected to largely contribute in reducing the budget of road constructions.

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